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IMPACT OF MANUFACTURING FLEXIBILITY ON MANUFACTURING PERFORMANCE AND BUSINESS PERFORMANCE AMONG MALAYSIAN MANUFACTURING FIRMS

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Universiti Utara Malaysia

DOCTOR OF PHILOSOPHY
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IMPACT OF MANUFACTURING FLEXIBILITY ON MANUFACTURING PERFORMANCE AND BUSINESS PERFORMANCE AMONG MALAYSIAN MANUFACTURING FIRMS

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ABSTRAK

Sorotan kepustakaan terdahulu menunjukkan terdapatnya penjelasan yang kabur mengenai hubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Bagi memenuhi jurang ini, kajian tentang impak keluwesan pembuatan terhadap prestasi pembuatan dan prestasi perniagaan telah dijalankan. Dalam kajian ini, pengkaji telah mencadangkan satu kerangka kerja pengantara apabila prestasi pembuatan berfungsi sebagai pengantara dalam hubungan di antara keluwesan pembuatan dan prestasi perniagaan. Komponen keluwesan pembuatan meliputi keluwesan campuran, keluwesan produk baru, keluwesan pekerja, keluwesan mesin, keluwesan pengendalian bahan, keluwesan penyaluran, dan keluwesan volum. Ukuran bagi prestasi pembuatan meliputi kualiti produk, pengurangan kos, produktiviti, pengurangan tempoh masa pembuatan dan pengurangan inventori. Sementara itu, prestasi perniagaan diukur oleh prestasi pasaran bagi produk, kepuasan pelanggan dan keberuntungan. Empat hipotesis utama telah dibentuk untuk menguji perhubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Kajian ini bersifat keratan rentas yang menggunakan metodologi tinjauan dan dijalankan ke atas lima industri perkilangan di Malaysia. Data diperolehi daripada 137 borang soal selidik yang dikembalikan dan telah dianalisis menggunakan analisis korelasi dan regresi. Keputusan analisis korelasi Pearson menunjukkan korelasi yang positif dan tinggi wujud dalam kalangan komponen keluwesan pembuatan. Di samping itu, dicadangkan bahawa komponen keluwesan pembuatan adalah saling bergantungan. Analisis regresi pula menyokong dapatan kajian bahawa keluwesan pembuatan mempunyai impak positif yang signifikan terhadap kedua-dua prestasi pembuatan dan prestasi perniagaan. Selain itu, kepentingan prestasi pembuatan sebagai pengantara dalam perhubungan keluwesan pembuatan dengan prestas perniagaan juga ditemui. Oleh itu, keluwesan pembuatan meningkatkan prestasi perniagaan secara langsung dan tidak langsung menerusi prestasi pembuatan sebagai pemboleh ubah pengantara. Secara spesifiknya, keempat-empat hipotesis utama yang diuji dalam kajian ini disokong. Kesimpulannya, kajian empirikal ini menyumbang dalam peningkatan pengetahuan dan kefahaman berkenaan saling perhubungan di antara keluwesan pembuatan, prestasi pembuatan dan prestasi perniagaan. Justeru, kajian ini membolehkan pihak penyelidik dan pengamal memperoleh pengetahuan yang lebih mendalam tentang konsep keluwesan pembuatan dan impaknya.

Kata kunci: keluwesan pembuatan, prestasi pembuatan, prestasi perniagaan, Malaysia

ABSTRACT

The unclear relationships between manufacturing flexibility, manufacturing performance and business performance have been indicated in past literature. To seal the gap, this study aimed to investigate the impact of manufacturing flexibility on manufacturing performance and business performance. In this study, the researcher proposed a mediating framework where manufacturing performance serves as a mediator in the relationship between manufacturing flexibility and business performance. The components of manufacturing flexibility were mix flexibility, new product flexibility, labor flexibility, machine flexibility, material handling flexibility, routing flexibility and volume flexibility. The measures for manufacturing performance were product quality, cost reduction, lead time reduction, productivity and inventory minimization. Product market performance, customer satisfaction and profitability were used as the measures for business performance. Four main hypotheses were developed to test the interrelationships between manufacturing flexibility, manufacturing performance and business performance. The study was a cross-sectional study, employing the survey methodology, conducted in five manufacturing industries in Malaysia. The data obtained from 137 returned questionnaires were analysed using correlational and regression analyses. Results of the correlation analyses indicated that components of manufacturing flexibility were positively and highly correlated among themselves, thus suggesting that the components were interdependent. Meanwhile, findings of the regression analyses provided support that manufacturing flexibility has significant positive impacts on both manufacturing performance and business performance. In addition, the mediation role of manufacturing performance on the relationship between manufacturing flexibility and business performance was revealed. In other words, manufacturing flexibility improves business performance both directly and indirectly via manufacturing performance as the mediator. Specifically, all four main hypotheses tested in this study were supported. In conclusion, this empirical study provides insights about the interrelationships between manufacturing flexibility, manufacturing performance and business performance. Hence, this study allows researchers and practitioners to gain in-depth knowledge about the concept of manufacturing flexibility and its impacts.

Keywords: manufacturing flexibility, manufacturing performance, business performance, Malaysia

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LIST OF ABBREVIATIONS

BP	Business Performance
CMV	Common Method Variance
GDP	Gross Domestic Product
KMO	Kaiser-Meyer-Olkin Measure
MF	Manufacturing Flexibility
MP	Manufacturing Performance
PCA	Principal Component Analysis
RBV	Resource-based View Theory
VIF	Variance Inflation Factor

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CHAPTER 1

INTRODUCTION

1.1 Background of the Research

In modern day, rapidly evolving business environments that are full with changes and uncertainty led to the need for flexibility. The increase of customers' expectation on the speed to fulfill their requirements have forced many organizations to act and respond faster, and to be more flexible to changes (Agus, 2011; Zhang, Vonderembse, & Lim, 2003). Traditional manufacturing approaches are no longer sufficient for a firm to secure competitive advantage in this drastically changing environment (Kaur, Kumar, & Kumar, 2016; Koste & Malhotra, 1999a).

Concurrently, rapid changes in world's technology have shortened the life cycle of the product; with customer demand for more innovative products with higher value, creating a flexible organization becomes essential to cope for rapid changes (Judi & Beach, 2008; Russell & Taylor, 2014). Decreasing of profit margins, increasing of inventory levels to cope with uncertainty, increasing of global competition, and increasing speed of technological changes (Agus, 2011; Judi & Beach, 2008; Kaur et al., 2016; Kher, Malhotra, Philipoom, & Fry, 1999; Mishra, Pundir, & Ganapathy, 2014; Nayak & Ray, 2012) have further amplified the need for flexibility. As a result, organizations must find better ways to meet these challenges. Since manufacturing flexibility enhances the ability of a firm to respond to customer needs that are highly diversified, it is generally accepted that incorporating manufacturing flexibility within the manufacturing function will help the organization to respond to such changes and customer needs in a faster and better way (Mishra et

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APPENDICES

Appendix A: Examples of Flexibility Components Focus by Past Researchers

Authors	Manufacturing Flexibility Components
Browne et al. (1984)	1. Expansion Flexibility 2. Machine Flexibility 3. Process Flexibility (similar to mix flexibility) 4. Product Flexibility (similar to new product flexibility) 5. Routing Flexibility 6. Volume Flexibility 7. Operation Flexibility 8. Production Flexibility
Swamidass and Newell (1987) Machinery and machine tools industry, US	Aggregated manufacturing Flexibility (instrument indicate it was a mixture of mix and new product flexibility.
Sethi and Sethi (1990)	1. Material Handling Flexibility 2. Machine Flexibility 3. Operation Flexibility 4. Process Flexibility (similar to mix flexibility) 5. Product Flexibility (similar to modification flexibility) 6. Routing Flexibility 7. Volume Flexibility 8. Expansion Flexibility 9. Program Flexibility 10. Production Flexibility 11. Market Flexibility
Gupta and Somers (1996) Precision machinery; Electrical and electronics; Industrial machinery; Metal products; Automobile and auto part firms, US	1. Expansion Flexibility 2. Material Handling Flexibility 3. Routing Flexibility 4. Machine Flexibility 5. Market Flexibility 6. Product Flexibility (similar to new product flexibility) 7. Process Flexibility (similar to mix flexibility) 8. Programming Flexibility 9. Volume Flexibility
Narasimhan and Das (1999) Mechanical subassembly; Automotive/heavy machinery; Electronics and electrical; Chemicals, US	1. Volume Flexibility 2. Modification Flexibility 3. New product Flexibility
Vokurka and O'Leary-Kelly (2000)	1. Machine Flexibility 2. Material Handling Flexibility 3. Operations Flexibility 4. Labor Flexibility 5. Process Flexibility (similar to mix flexibility) 6. Routing Flexibility 7. Product Flexibility (similar to new product flexibility) 8. New Design Flexibility (similar to new product flexibility) 9. Delivery Flexibility 10. Volume Flexibility 11. Expansion Flexibility 12. Program Flexibility 13. Production Flexibility 14. Market Flexibility

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Appendix A (Continued)

Authors	Manufacturing Flexibility Components
D'Souza and Williams (2000) Directory of Texas Manufacturers 1996 – Cross industries, US	1. Volume Flexibility 2. Variety Flexibility (mixture of new product flexibility and mix flexibility) 3. Process Flexibility (mixture of machine flexibility and mix flexibility) 4. Material Flexibility (similar to material handling flexibility)
Jack (2000) Various industries including aerospace, chemicals, machinery, agriculture, automotive, electronics and electrical, food, medical and health care, paper, utilities and also packaging, US	Volume Flexibility
Chang et al. (2002) Electronics, Taiwan	1. New Product Flexibility 2. Volume Flexibility 3. Product Mix Flexibility
Zhang et al. (2003) Fabricated metal products; Industrial/commercial machinery; Electronic and electrical; Transportation equipment; Measurements equipment, US	1. Mix Flexibility 2. Volume Flexibility 3. Flexible Manufacturing Competence (mixture of machine, labor material handling and routing flexibility)
Koste et al. (2004) Electronics; Machinery; Metal products, US	1. Machine Flexibility 2. Labor Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. New Product Flexibility 6. Modification Flexibility
Jantan et al. (2006) Electronics, Malaysia	1. Product Flexibility (similar to mix flexibility) 2. Volume Flexibility 3. Launch Flexibility (similar to new product flexibility)
Rogers (2008) Metal fabrication; Electronics; Automotive; Healthcare/medical devices; Aviation/aerospace; Food/beverages; Plastics/rubber; Electrical; Pharmaceuticals/Chemicals; Transportation; Software/Hardware, US	1. Mix Flexibility 2. Routing Flexibility 3. Volume Flexibility 4. Labor Flexibility 5. Supply Management Flexibility
Judi and Beach (2008) Electronics industry, UK and Malaysia	1. Volume Flexibility 2. Variety Flexibility (also known as mix flexibility) 3. Process Flexibility (similar to routing flexibility) 4. Material Handling Flexibility
Larso et al. (2009) Electronics, US	1. New Product Flexibility 2. Routing Flexibility 3. Modification Flexibility 4. Operation Flexibility 5. Labor Flexibility 6. Machine Flexibility 7. Material Handling Flexibility 8. Volume Flexibility

Appendix A (Continued)

Authors	Manufacturing Flexibility Components
Camisón and López (2010) 19 industries of Spanish industrial firms from SABI database excluding service, agricultural and energy sector, Spain	Aggregated manufacturing Flexibility (instrument indicate it was a mixture of mix, modification and volume flexibility)
Torres, Jose Benitez-Amado, Perez-Arostegui, and Barrales-Molina (2011) SABI database involved 30 industrial sectors, Spain	1. Routing Flexibility 2. Material Handling Flexibility
Tamayo-Torres et al. (2011) SABI database involved 30 industrial sectors, Spain	1. Routing Flexibility 2. Sequence Flexibility (similar to operation flexibility) 3. Modification Flexibility 4. Material Handling Flexibility 5. Machine Flexibility 6. Mix Flexibility
Rogers et al. (2011) Metal fabrication; Electronics; Automotive; Healthcare/medical devices; Aviation/aerospace; Food/beverages; Plastics/rubber; Electrical; Pharmaceuticals/Chemicals; Transportation; Software/Hardware, US	1. Mix Flexibility 2. Volume Flexibility 3. Machine Flexibility 4. Labor Flexibility 5. Routing Flexibility 6. Supplier Management flexibility
Patel et al. (2012)	1. Machine Flexibility 2. Labor Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. New Product Flexibility
Al-jawazneh (2012) Pharmaceutical, Jordan	1. Machine Flexibility 2. Volume Flexibility 3. Material Handling Flexibility 4. Mix Flexibility 5. Routing Flexibility
Chauhan and Singh (2014) Automotive; Machinery; Metal industries, India	1. Resource Flexibility (mixture of labor and machine flexibility)
Mendes and Machado (2014) Automotive industry; International (Europe, China, Brazil, US, Africa, Central America)	1. New Product Flexibility 2. Mix Flexibility 3. Volume Flexibility

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Appendix B: Definitions of Manufacturing Flexibility's Components for Past Study

Components of Manufacturing Flexibility	Definition	Author(s)
Mix Flexibility	The ability of a manufacturing system to switch between different products in the product mix.	Narasimhan and Das (1999)
	The number and variety of products can be produced without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The capability of producing a number of product lines or numerous variations within a line.	Berry and Cooper (1999)
	The ability of a given manufacturing system to cope with the changes related to product mix.	Gupta (2004)
	The ability to change the range of products made within a given time period.	Slack (2005)
	The ability of the system to produce many different products during the same planning period.	Judi and Beach (2008)
	The ability to offer a broad product line by switching quickly/easily between products.	Rogers (2008)
	The ability to produce variety of products.	Helkiö (2008)
	The ability to manufacture a wide range of products or variants with expected low changeover costs.	Fernandes, Gouveia, and Pinho (2012)
Volume Flexibility	The ability to operate an FMS profitably at different production volumes.	Browne et al. (1984)
	The ability to be operated profitably at different overall output levels.	Sethi and Sethi (1990)
	The ability to vary production with no detrimental effect on efficiency and quality.	Suarez et al. (1996)
	Capability of the system to respond to volume fluctuations and to expand production on short notice beyond normal installed capacity.	Narasimhan and Das (1999)
	The extent of change and the degree of fluctuation in aggregate output level which the system can accommodate without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to profitably increase or decrease aggregate production (output) in response to changes in customer demand.	Jack (2000)
	The ability of manufacturing system to overcome changes in the aggregate volume.	Gupta (2004)
	The ability to produce varying levels of output at a profit within a minimum planning period.	Sawhney (2006)
	The ability to change the level of aggregated output.	Slack (2005)
	The ability to operate profitably at different output volumes.	Rogers (2008)
	The ability to respond to varying levels of aggregate demand.	Helkiö (2008)
	The ability of the manufacturing system to change the volume or output of a manufacturing process.	Judi and Beach (2008)

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Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
New Product Flexibility	The ability of the manufacturing system to incorporate new product into the existing range of products.	Gupta and Somers (1992); Gupta and Somers (1996)
	The time starting from the earliest stage of design (customer product definition) and ending in the date when the first production batch of a "salable" product was made, after prototypes and pilot low-volume runs were completed.	Suarez et al. (1996)
	The number and variety of new products which are introduced into production without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	Capability of the firm to design, prototype, and produce new products to meet stringent time and cost constraints.	Narasimhan and Das (1999)
	The ability to introduce new products into production.	Helkiö (2008)
Machine Flexibility	The ease of making the changes required to produce a given set of part types.	Browne et al. (1984)
	Various types of operations that the machine can perform without requiring a prohibitive effort in switching from one operation to another.	Sethi and Sethi (1990)
	The number and variety of operations a machine performs without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of machines to perform variety of processing tasks.	Helkiö (2008)
Material handling Flexibility	The ability to move different part types efficiently for proper positioning and processing through the manufacturing facility it serves.	Sethi and Sethi (1990)
	The ability of the material handling system to move material effectively through the plant.	Narasimhan and Das (1999)
	The number of existing paths between processing centers and variety of material which can be transported along those paths without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of material handling system to transport multiple different materials and ability to transport materials via multiple different paths between processing centers.	Helkiö (2008)
	The ability of the material handling system to transport different materials between various processing centers over multiple paths.	Judi and Beach (2008)

Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
Labor Flexibility	The number and variety of operations a worker performs without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability of workers to perform multiple production tasks.	Helkiö (2008)
	The ability of workers to perform multiple tasks effectively.	Rogers (2008); Rogers et al. (2011)
Modification Flexibility	The number and variety of product modifications that are accomplished without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The amounts of product modifications which are accomplished without increasing change over time, changeover cost and scheduling efforts while maintain its quality, efficiency and productivity.	Koste and Malhotra (1999b)
	Capability of the system to make minor changes in product design to meet customization demand.	Narasimhan and Das (1999)
	The ability to accommodate product design changes in production.	Helkiö (2008)
	The ability to make minor modifications to existing products within a minimum planning period.	Larso et al. (2009)
Routing Flexibility	The ability to handle breakdowns and to continue producing the given set of part types.	Browne et al. (1984)
	The ability to produce a part by alternate routes through the system.	Sethi and Sethi (1990)
	The ability to vary machine visitation sequences for processing a part.	Narasimhan and Das (1999)
	The number of parts that have alternate routes and the extent of variation among the routes used without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to move different parts between machines/processing centers.	Rogers (2008)
	The ability to change the sequence of machines that perform operations.	Helkiö (2008)
	The ability to vary the path a part may take through the manufacturing system.	Nishith et al. (2013)
Delivery Flexibility	The ability of the system to respond to changes in delivery requests.	Vokurka and O'Leary-Kelly (2000)
	The ability to vary delivery schedule	Chang et al. (2003)
	The ability to change planned or assumed delivery dates.	Slack (2005)
	The ability to shorten or lengthen delivery times.	Sawhney (2006)

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Appendix B (Continued)

Components of Manufacturing Flexibility	Definition	Author(s)
Expansion Flexibility	The capability of building a system, and expanding it as needed, easily and modularly.	Browne et al. (1984)
	The ease with which its capacity and capability can be increased when needed.	Sethi and Sethi (1990)
	The ability to expand capacity without prohibitive effort.	Narasimhan and Das (1999)
	The number and variety of expansions which can be accommodated without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The ability to expand (capacity, capability) production system.	Helkiö (2008)
Program Flexibility	The ability of the system to run virtually untended for a long enough periods.	Sethi and Sethi (1990)
	The ability of equipment to run unattended for long periods of time.	Narasimhan and Das (1999)
Production Flexibility	The universe of part types that the FMS can produce.	Browne et al. (1984)
	The universe of part types that the manufacturing system can produce without adding major capital equipment.	Sethi and Sethi (1990)
	Range of products the system can produce without adding new equipment.	Vokurka and O'Leary-Kelly (2000)
Market Flexibility	The ease with which the manufacturing system can adapt to a changing market environment.	Sethi and Sethi (1990)
	The ability of the manufacturing system to adapt to or influence market changes.	Narasimhan and Das (1999)
	The ability to mass customize and build close relationships with customers, including design and modifying new and existing products.	Duclos et al. (2003)
Operations Flexibility	The ability to interchange the ordering of several operations for each part type.	Browne et al. (1984)
	The ability of a part to be produced in different ways.	Sethi and Sethi (1990)
	The number of parts that have alternate sequencing plans and the variety of the processing sequences used without incurring high transition penalties or large changes in performance outcomes.	Koste (1999)
	The number of alternative processes or ways in which a part can be produced within the system.	Vokurka and O'Leary-Kelly (2000)
	The ability to change the sequence of operations performed.	Helkiö (2008)
Supply Management Flexibility	Suppliers' ability to respond to buyer requests to adjust order quantities without significantly increasing lead time or unit cost.	Rogers (2008)

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Appendix C: Measurement Items

Appendix C1: Measurement Items of Manufacturing Flexibility Components

ID	Item	Literature
Mix Flexibility		
MX1	We economically change from producing one product to another.	Das (2001) and Judi and Beach (2008)
MX2	We vary the product combination from one period to the next.	Al-jawazneh (2012) and Rogers (2008)
MX3	We quickly change from producing one product to another.	Al-jawazneh (2012) and Judi and Beach (2008)
MX4	We produce different product types without major changeovers.	Al-jawazneh (2012) and Rogers (2008)
MX5	We easily change from producing one product to another.	Al-jawazneh (2012) and Rogers (2008)
New Product Flexibility		
N1	We frequently introduce new products into the production line.	Rogers (2008)
N2	The introduction of a new product into the production schedule is easy.	Koste (1999)
N3	We quickly add new product(s) into the existing range of products.	D'Souza and Williams (2000) and Koste (1999)
N4	We are able to produce new product types without major changeovers.	Proposed
N5	We are able to respond to customer requests for design changes in a given product.	Proposed
Labor Flexibility		
L1	Production workers are cross-trained to perform a variety of tasks.	Koste (1999) and Rogers (2008)
L2	Production workers are responsible for more than one task.	Chauhan and Singh (2014)
L3	Production workers are able to perform a wide range of operations economically.	Chauhan and Singh (2014) and Koste (1999)
L4	A typical production worker uses different tools effectively.	Rogers (2008)
L5	Production workers operate various types of machines.	Chang (2004) and Rogers (2008)
L6	Production workers can perform tasks which differ greatly from one another.	Chauhan and Singh (2014) and Koste (1999)
L7	We easily assign the production workers another task.	Chauhan and Singh (2014)

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Appendix C1 (Continued)

ID	Item	Literature
Machine Flexibility		
MC1	Machines are equally reliable for all operations.	Chauhan and Singh (2014); Koste (1999); Russell and Taylor (2014) and Tamayo-Torres et al. (2011)
MC2	Our production prefers to use general-purpose machine, which might be used to perform a number of operations.	Larso et al. (2009); Rogers (2008) and Russell and Taylor (2014)
MC3	When one machine is stopped, we can use different type of machine to perform the same tasks.	Hirano (1989) and Russell and Taylor (2014)
MC4	Our typical machine performs many types of operations.	Al-jawazneh (2012); Rogers (2008) and Russell and Taylor (2014)
MC5	Machines changeovers between operations are inexpensive.	Chauhan and Singh (2014) and Koste (1999)
Material Handling Flexibility		
MH1	The material handling system can handle a wide variety of parts.	Al-jawazneh (2012); Judi and Beach (2008); Larso et al. (2009) and Tamayo-Torres et al. (2011)
MH2	Material handling changeovers between parts can be done economically.	Judi and Beach (2008)
MH3	Material handling changeovers between parts can be done quickly.	Al-jawazneh (2012) and Judi and Beach (2008)
MH4	Material handling changeovers between parts can be done easily.	Al-jawazneh (2012) and Judi and Beach (2008)
MH5	Our material handling system handles different types of part.	Judi and Beach (2008) and Rogers (2008)
MH6	Our material handling system can be reconfigured quickly.	Al-jawazneh (2012) and Rogers (2008)

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Appendix C1 (Continued)

ID	Item	Literature
Routing Flexibility		
R1	The manufacturing system has alternative routes in case machines break down.	Al-jawazneh (2012); Rogers (2008) and Zhang et al. (2003)
R2	A typical part operation can be routed to different machines.	Al-jawazneh (2012) and Rogers (2008)
R3	We use many different routes to produce a product type.	Judi and Beach (2008) and Rogers (2008)
R4	We are able to change sequence of steps in production process economically.	Judi and Beach (2008)
R5	Machine visitation sequence can be changed quickly.	Al-jawazneh (2012) and Rogers (2008)
R6	Routing paths for manufacturing products can be changed economically.	Koste (1999) and Larso (2004)
Volume Flexibility		
V1	We run a range of production volumes.	Al-jawazneh (2012); Judi and Beach (2008) and Koste (1999)
V2	Output rates for all products can be varied.	Al-jawazneh (2012) and Koste (1999)
V3	We are able to increase or decrease our production volume quickly.	Judi and Beach (2008) and Larso et al. (2009)
V4	We are able to run various batch sizes.	Al-jawazneh (2012) and Rogers (2008)
V5	We are able to increase or decrease our production volume easily.	Al-jawazneh (2012); Koste (1999) and Rogers (2008)
V6	We vary total quantity of output from one period to the next.	Al-jawazneh (2012)

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Appendix C2: Measurement Items of Manufacturing Performance

ID	Item	Literature
Product Quality		
Q1	We are able to produce quality products.	Al-jawazneh (2012) and Nawanir et al. (2013)
Q2	We have superior product quality compared to our competitors'.	Nawanir et al. (2013)
Q3	The percentage of poor quality products that must be scrapped has reduced.	Nawanir et al. (2013)
Q4	The percentage of production outputs that do not meet quality specifications has reduced.	Nawanir et al. (2013)
Q5	The percentage of products that pass final inspection the first time (first-pass yield) has increased.	Nawanir et al. (2013) and Russell and Taylor (2014)
Cost Reduction		
CR1	Our total manufacturing cost (including labor, material and overhead) to produce the product has reduced.	Al-jawazneh (2012) and Das (2001)
CR2	Our unit manufacturing cost has reduced (unit manufacturing cost is the total cost for producing the units divided by the number of units produced).	Al-jawazneh (2012); Nawanir et al. (2013) and Rogers (2008)
CR3	Our unit manufacturing cost is lower than the competitors.	Al-jawazneh (2012) and Nawanir et al. (2013)
CR4	Our internal failure costs (i.e., cost of defect, scrap, rework, process failure, and downtime) have reduced.	Nawanir et al. (2013) and Rogers (2008)
CR5	Our external failure costs (i.e., complaints, returns, warranty claims, liability and lost sales) have reduced.	Nawanir et al. (2013)
CR6	Our total inventory costs (costs related to storing and maintaining the inventory such as raw materials, work in process, and finished goods over a certain period of time) has reduced.	Sambasivan et al. (2009)

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Appendix C2 (Continued)

ID	Item	Literature
Lead Time Reduction		
LR1	Our manufacturing cycle time (i.e., from raw material to finished goods) is competitive.	Al-jawazneh (2012); Nawanir et al. (2013) and Russell and Taylor (2014)
LR2	The moving times for materials from storage to workstation have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR3	Machine setup times have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR4	The times required to perform the productive operations have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR5	The moving times for parts between workstations have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
LR6	The queuing times for parts waiting for the works to begin because another order is being processed at a workstation have reduced.	Nawanir et al. (2013) and Russell and Taylor (2014)
Productivity		
PT1	Productivity of our production line has increased due to more efficient machine setups.	Nawanir et al. (2013)
PT2	Productivity of our production line has increased due to more efficient production processes.	Nawanir et al. (2013)
PT3	Productivity of our production line has increased due to reduced inputs (such as labor, material and overhead).	Nawanir et al. (2013)
PT4	Our machine productivity has increased.	Nawanir et al. (2013)
PT5	The overall productivity of our production line has been outstanding.	Nawanir et al. (2013)
Inventory Minimization		
IM1	Work-in-process (WIP) inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM2	Raw material inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM3	Finished goods inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM4	Overall inventory level has reduced.	Nawanir et al. (2013) and Rogers (2008)
IM5	Storage space requirement has reduced.	Nawanir et al. (2013)

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Appendix C3: Measurement Items of Business Performance

ID	Item	Literature
Profitability		
PF1	Our revenue growth rate has been outstanding.	Carton and Hofer (2006); Nawanir et al. (2013) and Santos and Brito (2012)
PF2	Our ability to earn a profit has exceeded our competitors'.	Carton and Hofer (2006) and Nawanir et al. (2013)
PF3	Our return on investment (ratio of net income to total investment) reflects sound investments.	Carton and Hofer (2006); Nawanir et al. (2013) and Santos and Brito (2012)
PF4	Our overall financial performance has been outstanding.	Carton and Hofer (2006) and Chearskul (2010)
Product Market Performance		
PM1	Our market share has increased significantly.	Nawanir et al. (2013) and Richard et al. (2009)
PM2	Our market share growth has exceeded our competitors'.	Nawanir et al. (2013) and Richard et al. (2009)
PM3	Our sales (in volume) growth has been outstanding.	Camisón and López (2010); Nawanir et al. (2013) and Richard et al. (2009)
Customer Satisfaction		
CS1	Our customer satisfaction performance has exceeded our competitors'.	Jack (2000) and Nawanir et al. (2013)
CS2	Our customers are satisfied with the quality of our products.	Nawanir et al. (2013) and Zhang et al. (2009)
CS3	Our customers are satisfied with our on time delivery performance.	Jack (2000) and Nawanir et al. (2013)
CS4	Our customers are satisfied with our ability to respond to customer changing needs.	Proposed
CS5	The number of customer complaints has reduced.	Sambasivan et al. (2009) and (Santos and Brito (2012))

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Appendix D: Letter for Data Collection and Research Work

OTHMAN YEOP ABDULLAH
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KEDAH AMAN MAKMUR • BERSAMA MEMACU TRANSFORMASI

UUM/OYAGSB/R-4/4/1
03 December 2015

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER FOR DATA COLLECTION AND RESEARCH WORK

This is to certify that **Tan Kong Woun (Matric No: 91438)** is a bonafied student of Doctor of Philosophy (PhD), Othman Yeop Abdullah Graduate School of Business, Universiti Utara Malaysia. He is conducting a research entitled ***"Manufacturing Flexibility, Manufacturing Performance and Business Performance : An Empirical Study in Malaysia."*** under the supervision of Assoc. Prof. Dr. Lim Kong Teong and Assoc. Prof Dr. Siti Norezam B Othman.

In this regard, I hope that you could kindly provide assistance and cooperation for him to successfully complete the research. All the information gathered will be strictly used for academic purposes only.

Your cooperation and assistance is very much appreciated.

Thank you.

"KNOWLEDGE, VIRTUE, SERVICE"

Yours faithfully,

ROZITA BINTI RAMLI
Assistant Registrar
for Dean
Othman Yeop Abdullah Graduate School of Business

c.c - Supervisor
- Student's File (91438)

Appendix E: Survey Questionnaire

RESEARCH ON MANUFACTURING FLEXIBILITIES AND PERFORMANCE OF MALAYSIA MANUFACTURING COMPANIES

General Information:
This is a PhD research to determine the impact of the manufacturing practices, which are consistent with the manufacturing flexibility philosophy, on organizational performance. The researchers believed that the outcome of this research will be of immense benefits to improve the performance in the Malaysia manufacturing sector. Your effort in filling the questionnaire is highly appreciated in order to produce a quality research.

General Instruction:
The questionnaire consists of four sections. Please read the items carefully before answering. You are expected to choose the answer that represents your opinion. Your answer plays an important role in the success of this study and you are assured that such information will be treated with **utmost confidentiality**. Please tick, circle the appropriate answer or complete the answer in the space provided.

Thanks for your participation.

Tan Kong Woun goodiestan2002@yahoo.com +60129839575
PhD Candidate

Assoc. Prof. Dr. Lim Kong Teong ktlim@uum.edu.my +6049286952
Main Supervisor

Assoc. Prof. Dr. Siti Norezam Othman norezam@uum.edu.my +6049286954
Co-supervisor

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Section One: Company's Background Information

Nature of your business

☐ Basic metals and fabricated metal products
☐ Machinery & Equipment
☐ Electronic, electrical equipment and components
☐ Chemicals and Chemical Products
☐ Food Products and Beverages
☐ Others (please specify): _____

Company's ownership

☐ State owned enterprise
☐ Private enterprise
☐ Foreign invested enterprise
☐ Joint venture
☐ Others (please specify): _____

Number of employees

☐ <50 employees
☐ 50 – 99 employees
☐ 100 – 149 employees
☐ 150 - 199 employees
☐ 200 – 499 employees
☐ 500 employees and above

Annual sales 2015

☐ Less than RM 10 million
☐ RM 10 million – RM 25 million
☐ More than RM 25 million to RM50 million
☐ More than RM50 million

Products Manufactured (please specify):

_____

_____

_____

Which of the following process type best represent your production process?

☐ Job shop process (Low production volume, High variety)
☐ Batch process (Medium production volume, Medium variety)
☐ Repetitive process (High production volume, Low variety)
☐ Continuous flow process (Very High production volume, No variety)
☐ Mass Customization process (Very High production volume, High variety)
☐ Others (please specify): _____

Your position in the company

☐ Director of production/manufacturing
☐ Head of production/manufacturing department
☐ Manager of production/manufacturing
☐ Others (please specify): _____

How long have you been working in this company?

☐ Less than 3 years
☐ 3 – 5 years
☐ 6 – 10 years
☐ More than 10 years

How long have you been in the current position?

☐ Less than 1 year
☐ 1 – 3 years
☐ 4 – 10 years
☐ More than 10 years

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Section Two: Manufacturing Flexibility

Direction:
This section focuses on the level of manufacturing flexibility capabilities in your manufacturing system. It addresses the components of Manufacturing Flexibility representing each of the dimensions.

On the following scale, please evaluate the level of mix flexibility and new product flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
A. Mix Flexibility – The ability of the manufacturing system to switch between different products in the product mix.						
1. We economically change from producing one product to another.	**1**	**2**	**3**	**4**	**5**	**6**
2. We vary the product combination from one period to the next.	**1**	**2**	**3**	**4**	**5**	**6**
3. We quickly change from producing one product to another.	**1**	2	3	**4**	**5**	**6**
4. We produce different product types without major changeovers.	**1**	**2**	**3**	**4**	**5**	**6**
5. We easily change from producing one product to another.	**1**	2	3	**4**	**5**	**6**
B. New Product Flexibility – The ability of the manufacturing system to incorporate new product(s) into the existing range of products.						
1. We frequently introduce new products into the production line.	**1**	**2**	**3**	**4**	**5**	**6**
2. The introduction of a new product into the production schedule is easy.	**1**	**2**	**3**	**4**	**5**	**6**
3. We quickly add new product(s) into the existing range of products.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to produce new product types without major changeovers.	**1**	**2**	**3**	**4**	**5**	**6**
5. We are able to respond to customer requests for design changes in a given product.	**1**	**2**	**3**	**4**	**5**	**6**

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On the following scale, please evaluate the level of labor flexibility and machine flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
C. Labor Flexibility – The ability of production workers to perform more than one task in the manufacturing system.						
~~1. Production workers are cross-trained to perform a variety of tasks.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. Production workers are responsible for more than one task.	**1**	**2**	**3**	**4**	**5**	**6**
3. Production workers are able to perform a wide range of operations economically.	**1**	**2**	**3**	**4**	**5**	**6**
4. A typical production worker uses different tools effectively.	**1**	**2**	**3**	**4**	**5**	**6**
5. Production workers operate various types of machines.	**1**	**2**	**3**	**4**	**5**	**6**
6. Production workers can perform tasks which differ greatly from one another.	**1**	**2**	**3**	**4**	**5**	**6**
7. We easily assign the production workers another task.	**1**	**2**	**3**	**4**	**5**	**6**
D. Machine Flexibility – The ability of the manufacturing machine to perform more than one operation to produce different parts or products.						
1. Machines are equally reliable for all operations.	**1**	**2**	**3**	**4**	**5**	**6**
2. Our production prefers to use general-purpose machine, which might be used to perform a number of operations.	**1**	**2**	**3**	**4**	**5**	**6**
3. When one machine is stopped, we can use different type of machine to perform the same tasks.	**1**	**2**	**3**	**4**	**5**	**6**
4. Our typical machine performs many types of operations.	**1**	**2**	**3**	**4**	**5**	**6**
~~5. Machines changeovers between operations are inexpensive.~~	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.8)

On the following scale, please evaluate the level of material handling flexibility, routing flexibility and volume flexibility in your manufacturing system by circling the appropriate number.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
E. Material Handling Flexibility – The ability of material handling system to handle various types of material.						
1. The material handling system can handle a wide variety of parts.	**1**	**2**	**3**	**4**	**5**	**6**
2. Material handling changeovers between parts can be done : a. economically.	**1**	**2**	**3**	**4**	**5**	**6**
b. quickly	**1**	**2**	**3**	**4**	**5**	**6**
c. easily	**1**	**2**	**3**	**4**	**5**	**6**
3. Our material handling system handles different types of part.	**1**	**2**	**3**	**4**	**5**	**6**
4. Our material handling system can be reconfigured quickly.	**1**	**2**	**3**	**4**	**5**	**6**
F. Routing Flexibility – The ability of the manufacturing system to manufacture products through a variety of different routes.						
1. The manufacturing system has alternative routes in case machines break down	**1**	**2**	**3**	**4**	**5**	**6**
2. A typical part operation can be routed to different machines.	**1**	**2**	**3**	**4**	**5**	**6**
3. We use many different routes to produce a product type.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to change sequence of steps in production process economically	**1**	**2**	**3**	**4**	**5**	**6**
5. Machine visitation sequence can be changed quickly.	**1**	**2**	**3**	**4**	**5**	**6**
6. Routing paths for manufacturing products can be changed economically.	**1**	**2**	**3**	**4**	**5**	**6**
G. Volume flexibility – The ability of the manufacturing system to alter the output volume of a manufacturing process.						
~~1. We run a range of production volumes.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. Output rates for all products can be varied.	**1**	**2**	**3**	**4**	**5**	**6**
3. We are able to increase or decrease our production volume quickly.	**1**	**2**	**3**	**4**	**5**	**6**
4. We are able to run various batch sizes.	**1**	**2**	**3**	**4**	**5**	**6**
5. We are able to increase or decrease our production volume easily.	**1**	**2**	**3**	**4**	**5**	**6**
~~6. We vary total quantity of output from one period to the next.~~	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.8)

Section Three: Manufacturing Performance

Directions:
This section focuses on the manufacturing performance of your plant during the past three years. It examines the level of manufacturing performance of the plant through five main perspectives of achievements namely product quality, cost reduction, lead time reduction, productivity and inventory minimization.

On the following scale, please circle the appropriate number which best reflect your perception.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
A. Product Quality						
1. We are able to produce quality products.	1	2	3	4	5	6
2. We have superior product quality compared to our competitors'.	1	2	3	4	5	6
3. The percentage of poor quality products that must be scrapped has reduced.	1	2	3	4	5	6
4. The percentage of production outputs that do not meet quality specifications has reduced.	1	2	3	4	5	6
5. The percentage of products that pass final inspection the first time (first-pass yield) has increased.	1	2	3	4	5	6
B. Cost Reduction						
1. Our total manufacturing cost (including labor, material and overhead) to produce the product has reduced.	1	2	3	4	5	6
2. Our unit manufacturing cost has reduced (unit manufacturing cost is the total cost for producing the units divided by the number of units produced).	1	2	3	4	5	6
3. Our unit manufacturing cost is lower than the competitors.	1	2	3	4	5	6
4. Our internal failure costs (i.e., cost of defect, scrap, rework, process failure, and downtime) have reduced.	1	2	3	4	5	6
~~5. Our external failure costs (i.e., complaints, returns, warranty claims, liability and lost sales) have reduced.~~	1	2	3	4	5	6
~~6. Our total inventory costs (costs related to storing and maintaining the inventory such as raw materials, work in process, and finished goods over a certain period of time) has reduced.~~	1	2	3	4	5	6

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

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On the following scale, please circle the appropriate number which best reflect your perception.

Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

Items/Statements	Level of Agreement					
C. Lead time reduction						
~~1. Our manufacturing cycle time (from raw material to finished goods) is competitive.~~	**1**	**2**	**3**	**4**	**5**	**6**
2. The moving times for materials from storage to workstation have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
3. Machine setup times have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
4. The times required to perform the productive operations have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
5. The moving times for parts between workstations have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
6. The queuing times for parts waiting for the works to begin because another order is being processed at a workstation have reduced.	**1**	**2**	**3**	**4**	**5**	**6**
D. Productivity						
1. Productivity of our production line has increased due to: a. More efficient machine setups	**1**	**2**	**3**	**4**	**5**	**6**
b. More efficient production processes.	**1**	**2**	**3**	**4**	**5**	**6**
c. Reduced inputs (such as labor, material and overhead)	**1**	2	3	**4**	**5**	**6**
2. Our machine productivity has increased.	1	2	3	**4**	**5**	**6**
3. The overall productivity of our production line has been outstanding.	1	2	3	**4**	**5**	**6**
E. Inventory Minimization						
1. Work-in-process (WIP) inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
~~2. Raw material inventory level has reduced.~~	**1**	**2**	**3**	**4**	**5**	**6**
3. Finished goods inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
4. Overall inventory level has reduced.	**1**	**2**	**3**	**4**	**5**	**6**
5. Storage space requirement has reduced.	**1**	**2**	**3**	**4**	**5**	**6**

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

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Section Four: Business Performance

Directions:

This section focuses on the business performance of your plant <u>during the past three years</u>. It examines the level of business performance of the plant through three main perspectives of achievements namely profitability, product market performance, and customer satisfaction.

On the following scale, please circle the appropriate number which best reflect your perception on profitability, sales and customer satisfaction for your plant.

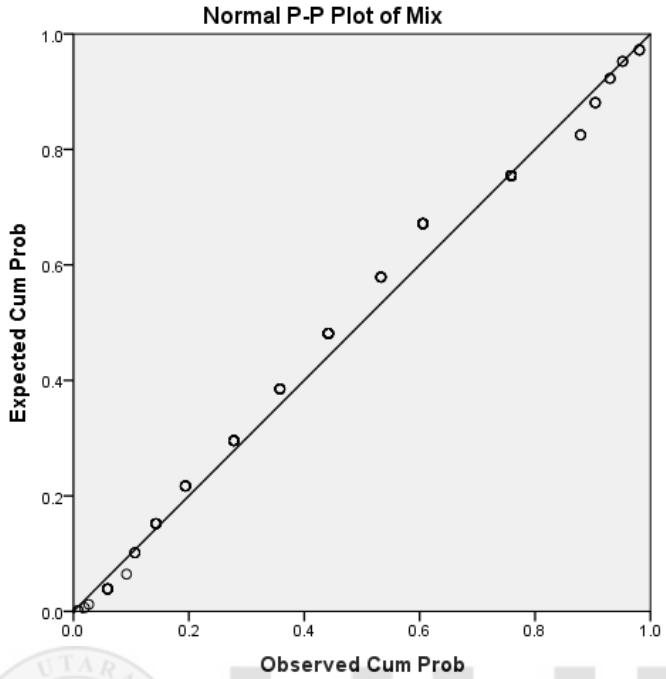
Strongly Disagree	Disagree	Somewhat disagree	Somewhat agree	Agree	Strongly Agree
1	2	3	4	5	6

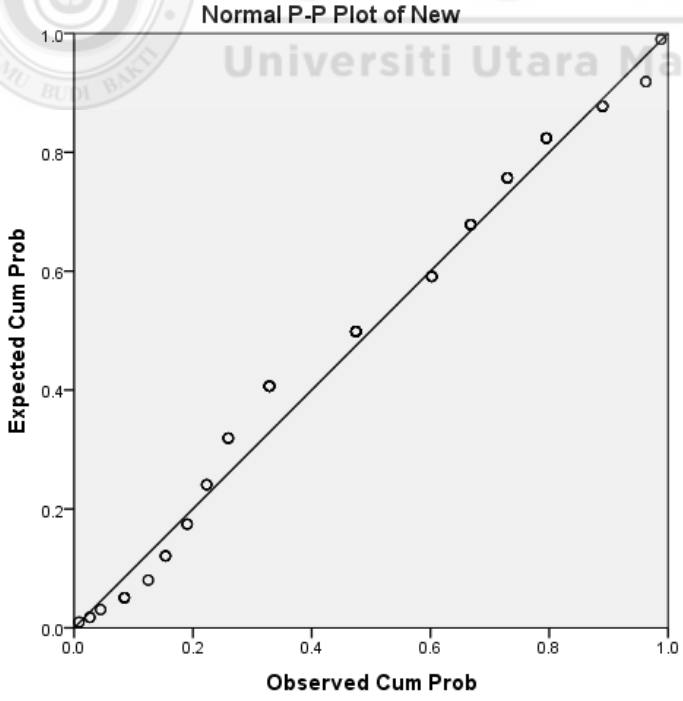
Items/Statements	Level of Agreement					
A. Profitability						
1. Our revenue growth rate has been outstanding.	1	2	3	4	5	6
2. Our ability to earn a profit has exceeded our competitors'.	1	2	3	4	5	6
3. Our return on investment (ratio of net income to total investment) reflects sound investments.	1	2	3	4	5	6
4. Our overall financial performance has been outstanding.	1	2	3	4	5	6
B. Product Market Performance						
1. Our market share has increased significantly.	1	2	3	4	5	6
2. Our market share growth has exceeded our competitors'.	1	2	3	4	5	6
~~3. Our sales (in volume) growth has been outstanding.~~	1	2	3	4	5	6
C. Customer Satisfaction						
1. Our customer satisfaction performance has exceeded our competitors'.	1	2	3	4	5	6
2. Our customers are satisfied with: (a) The quality of our products.	1	2	3	4	5	6
(b) Our on time delivery performance.	1	2	3	4	5	6
(c) Our ability to respond to customer changing needs.	1	2	3	4	5	6
3. The number of customer complaints has reduced.	1	2	3	4	5	6

Please send this completed survey booklet in the enclosed self-address envelope provided. Thank you for your participation and your time in answering the survey.

Remark: Strikethrough sentences are omitted items with factor loading less than 0.70 (refer Table 4.9)

Appendix F: Normal Probability Plots





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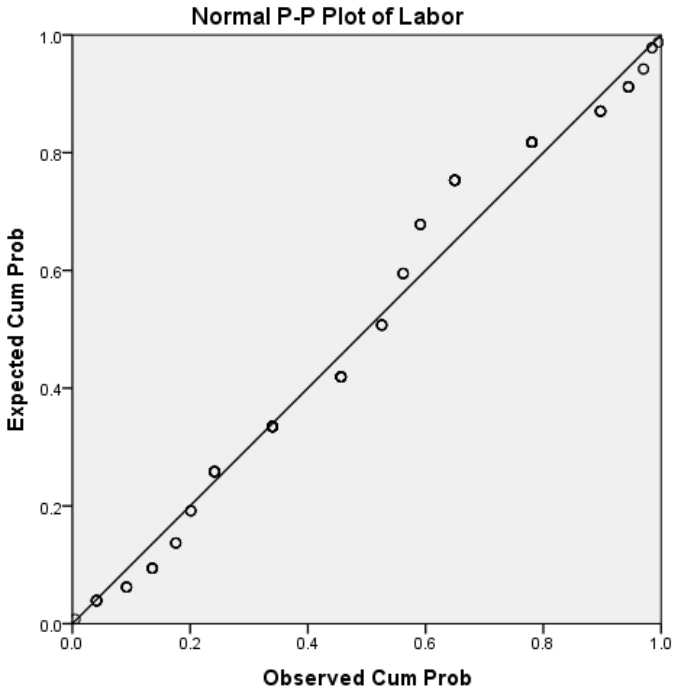

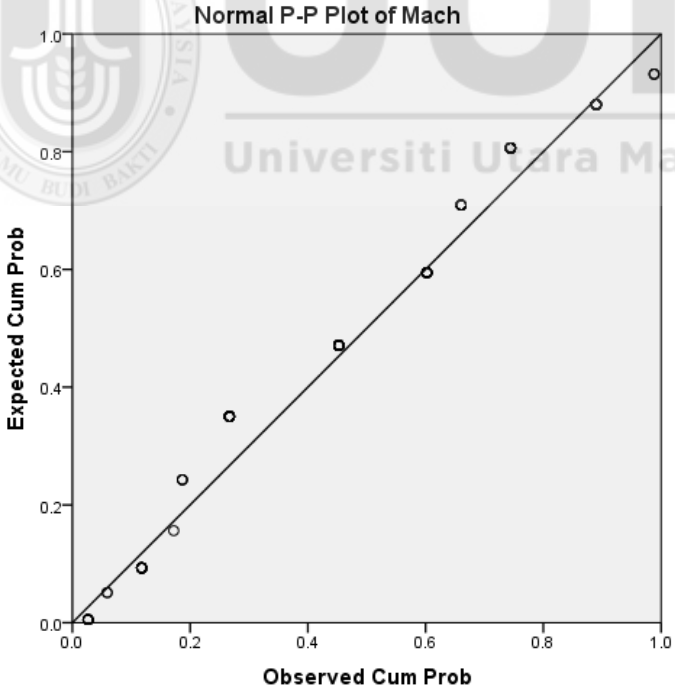

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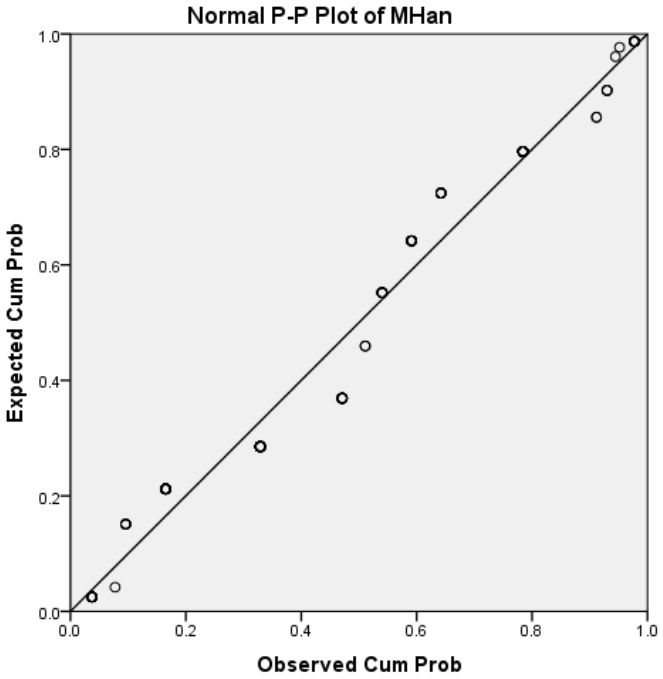

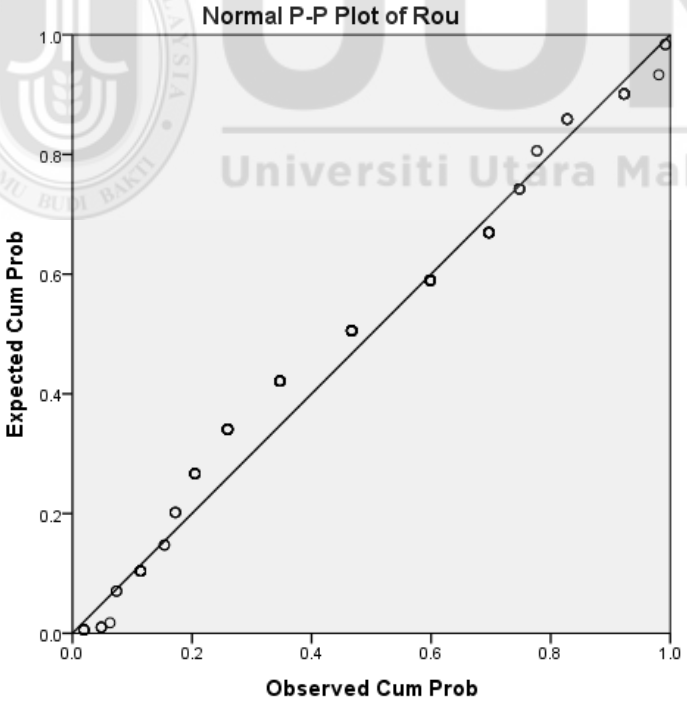

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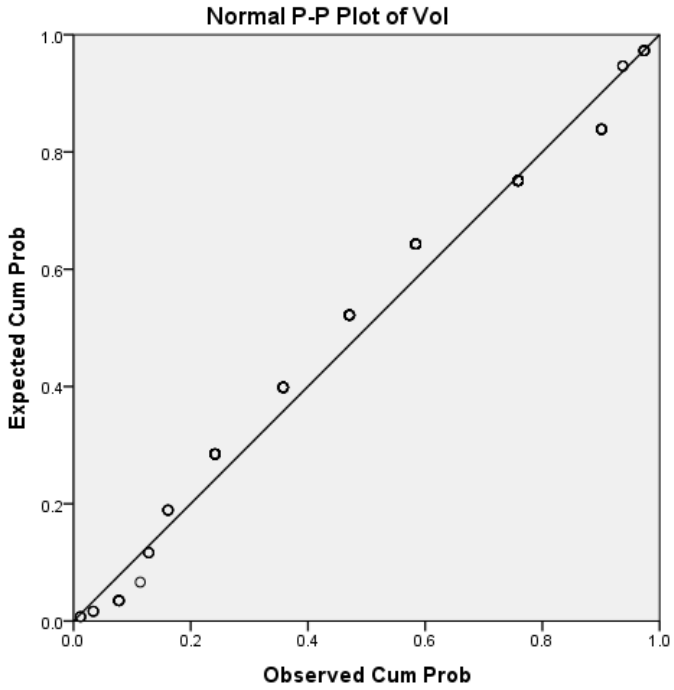

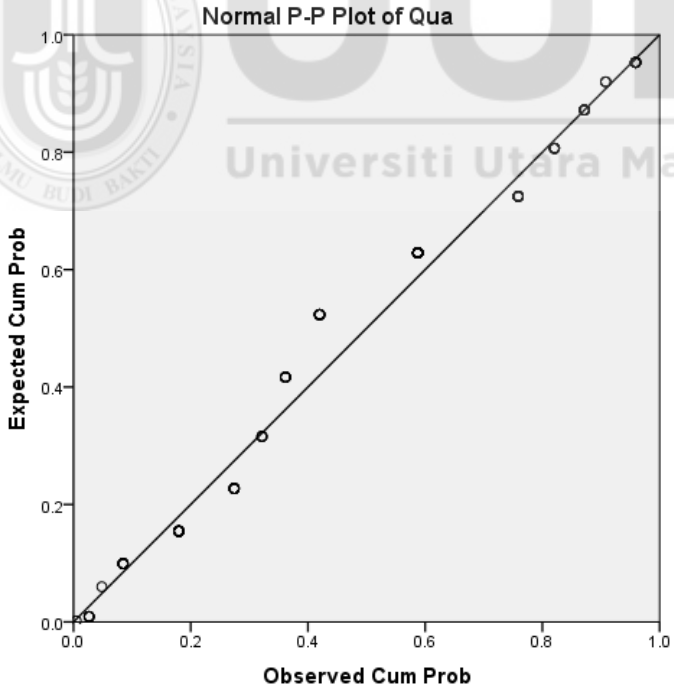

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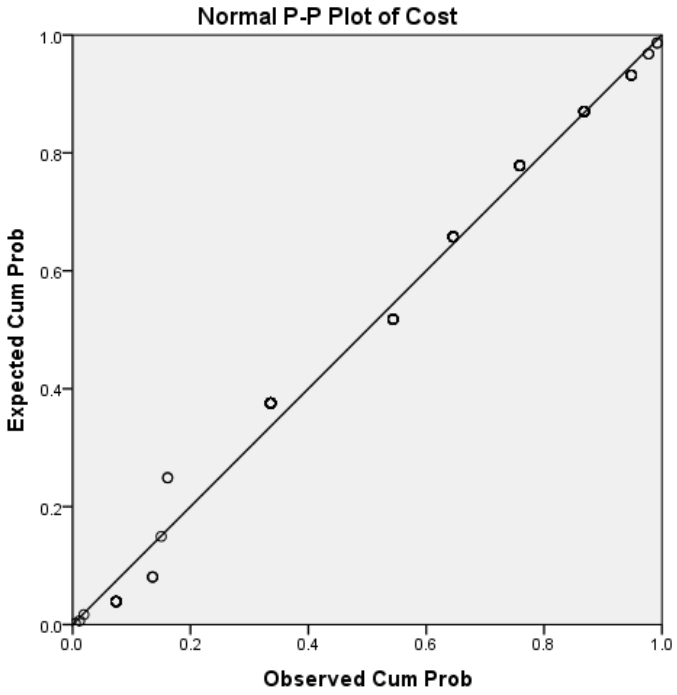

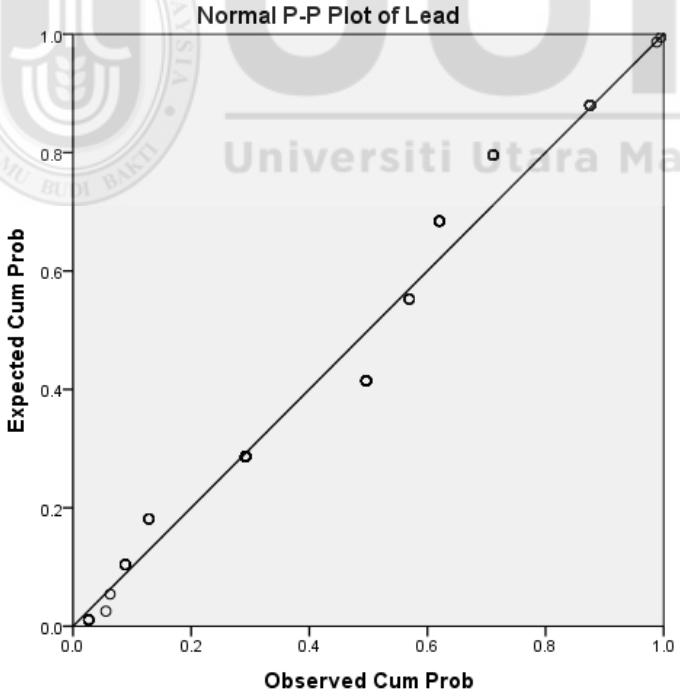

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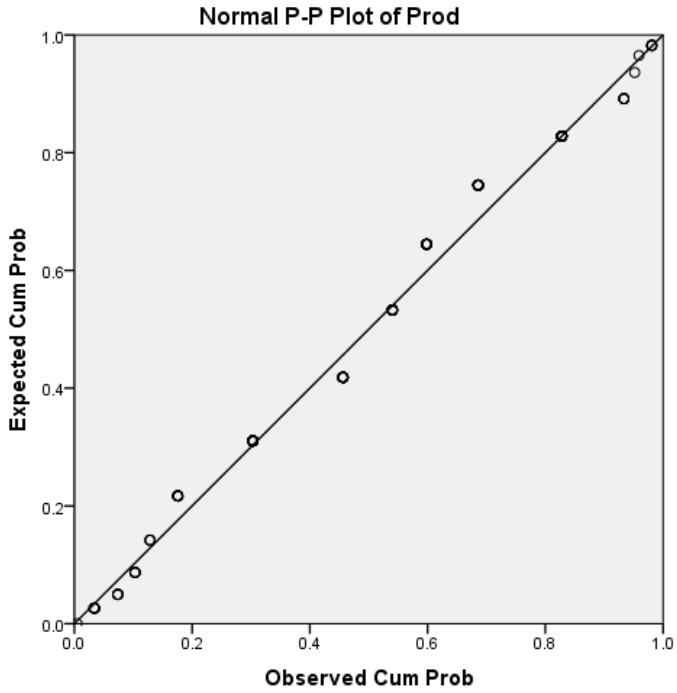

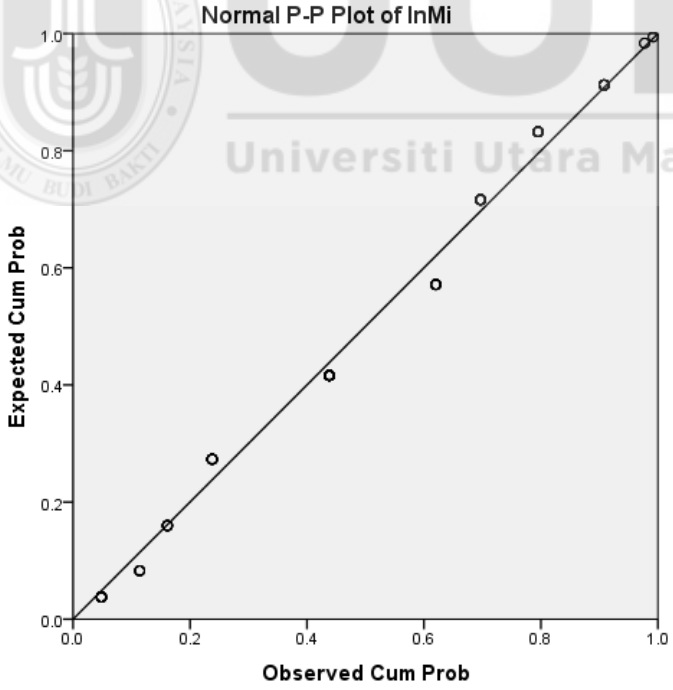

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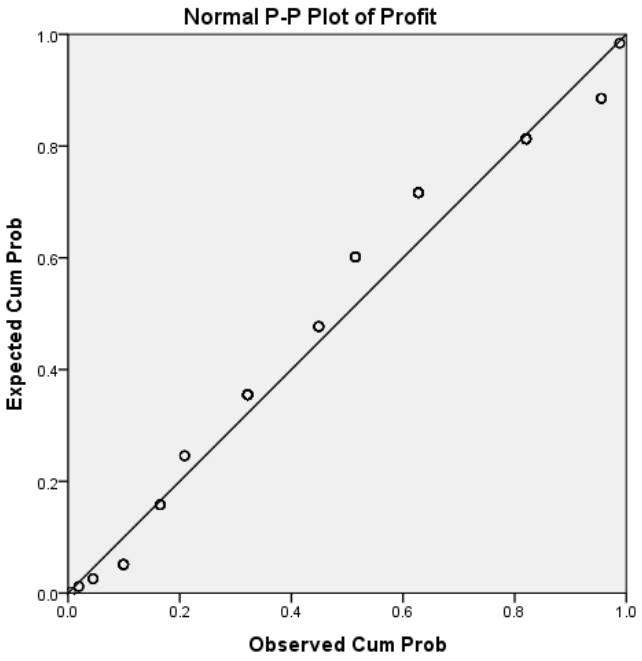

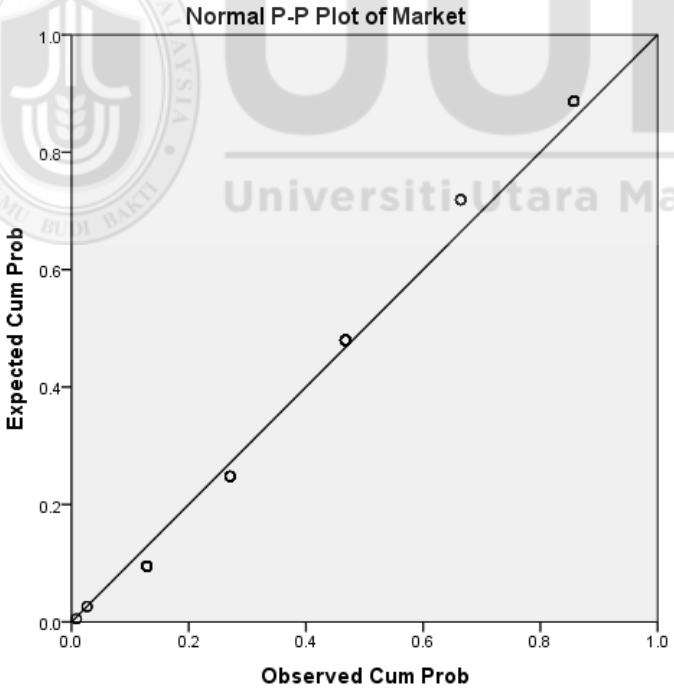

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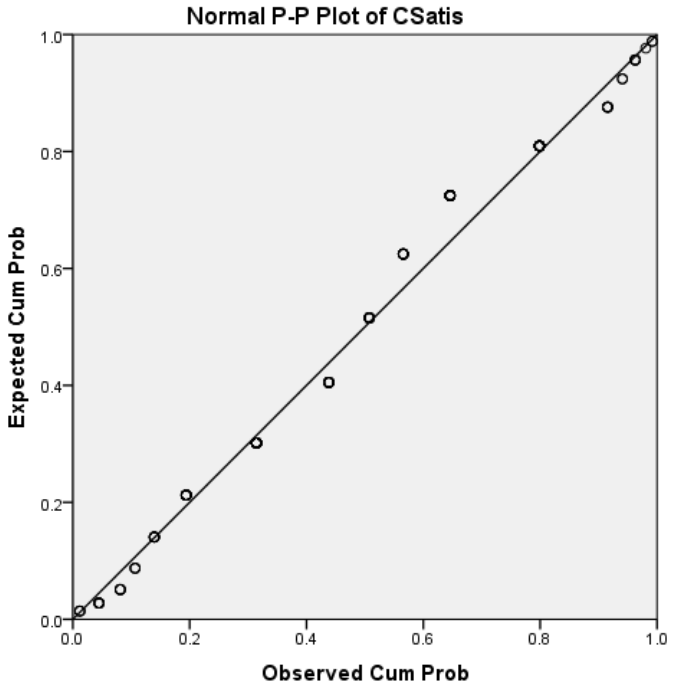

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Appendix G: Regression Analysis Manufacturing Flexibility Components on Manufacturing Performance

Quality

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Qua
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.761[a]	.579	.557	.49512

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	43.554	7	6.222	25.381	.000[b]
	Residual	31.624	129	.245		
	Total	75.177	136			

a. Dependent Variable: Qua
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.206	.305		3.961	.000
	Mix	.271	.063	.298	4.334	.000
	New	-.218	.070	-.251	-3.115	.002
	Labor	-.201	.103	-.203	-1.956	.053
	Mach	-.187	.080	-.201	-2.326	.022
	MHan	.558	.105	.538	5.339	.000
	Rou	.314	.081	.332	3.872	.000
	Vol	.254	.093	.274	2.721	.007

a. Dependent Variable: Qua

Cost Reduction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Cost
b. All requested variables entered.

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Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.764[a]	.583	.561	.45894

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.010	7	5.430	25.781	.000[b]
	Residual	27.171	129	.211		
	Total	65.181	136			

a. Dependent Variable: Cost
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.097	.282		3.885	.000
	Mix	.078	.058	.092	1.352	.179
	New	.051	.065	.063	.791	.431
	Labor	.108	.095	.117	1.133	.259
	Mach	-.247	.074	-.285	-3.317	.001
	MHan	.121	.097	.125	1.250	.213
	Rou	.485	.075	.550	6.448	.000
	Vol	.143	.087	.166	1.651	.101

a. Dependent Variable: Cost

Lead Time Reduction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Lead
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.761[a]	.579	.556	.38361

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	26.067	7	3.724	25.306	.000[b]
	Residual	18.983	129	.147		
	Total	45.051	136			

a. Dependent Variable: Lead
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

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Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.435	.236		6.084	.000
	Mix	.221	.049	.313	4.556	.000
	New	.226	.054	.336	4.168	.000
	Labor	.020	.080	.026	.249	.804
	Mach	-.264	.062	-.368	-4.252	.000
	MHan	.300	.081	.373	3.702	.000
	Rou	.117	.063	.160	1.868	.064
	Vol	.046	.072	.063	.628	.531

a. Dependent Variable: Lead

Productivity

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Prod

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.780[a]	.608	.587	.44591

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

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ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.786	7	5.684	28.585	.000[b]
	Residual	25.650	129	.199		
	Total	65.436	136			

a. Dependent Variable: Prod

b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.682	.274		2.488	.014
	Mix	.112	.056	.131	1.979	.050
	New	.051	.063	.063	.805	.422
	Labor	.057	.093	.062	.616	.539
	Mach	-.034	.072	-.040	-.475	.636
	MHan	.327	.094	.338	3.475	.001
	Rou	.266	.073	.301	3.645	.000
	Vol	.079	.084	.091	.939	.349

a. Dependent Variable: Prod

Inventory Minimization

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: InMi
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.710[a]	.504	.477	.46166

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.883	7	3.983	18.690	.000[b]
	Residual	27.494	129	.213		
	Total	55.377	136			

a. Dependent Variable: InMi
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.141	.284		4.018	.000
	Mix	.216	.058	.276	3.702	.000
	New	.061	.065	.082	.933	.352
	Labor	.145	.096	.171	1.516	.132
	Mach	-.031	.075	-.038	-.409	.683
	MHan	-.100	.097	-.112	-1.023	.308
	Rou	.204	.076	.251	2.701	.008
	Vol	.205	.087	.257	2.349	.020

a. Dependent Variable: InMi

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Appendix H: Regression Analysis Manufacturing Flexibility Components on Business Performance

Profitability

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Profit
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.825[a]	.681	.663	.46042

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	58.306	7	8.329	39.292	.000[b]
	Residual	27.346	129	.212		
	Total	85.652	136			

a. Dependent Variable: Profit
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.240	.283		-.848	.398
	Mix	.409	.058	.420	7.020	.000
	New	.070	.065	.076	1.077	.283
	Labor	.096	.096	.091	1.008	.315
	Mach	-.213	.075	-.215	-2.860	.005
	MHan	.283	.097	.256	2.913	.004
	Rou	.350	.075	.346	4.641	.000
	Vol	.056	.087	.056	.639	.524

a. Dependent Variable: Profit

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Product Market Performance

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: Market
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.792[a]	.627	.607	.49703

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53.661	7	7.666	31.030	.000[b]
	Residual	31.869	129	.247		
	Total	85.529	136			

a. Dependent Variable: Market
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.106	.306		.347	.729
	Mix	.532	.063	.547	8.458	.000
	New	.081	.070	.087	1.151	.252
	Labor	-.034	.103	-.032	-.328	.743
	Mach	-.384	.081	-.388	-4.771	.000
	MHan	.216	.105	.195	2.058	.042
	Rou	.567	.081	.562	6.971	.000
	Vol	-.058	.094	-.058	-.614	.540

a. Dependent Variable: Market

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Customer Satisfaction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Vol, Mix, New, Rou, Mach, MHan, Labor[b]	.	Enter

a. Dependent Variable: CSatis
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.746[a]	.557	.533	.48994

a. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	38.890	7	5.556	23.145	.000[b]
	Residual	30.965	129	.240		
	Total	69.855	136			

a. Dependent Variable: CSatis
b. Predictors: (Constant), Vol, Mix, New, Rou, Mach, MHan, Labor

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.677	.301		2.246	.026
	Mix	.228	.062	.259	3.677	.000
	New	-.004	.069	-.005	-.059	.953
	Labor	-.074	.102	-.077	-.726	.469
	Mach	.134	.079	.149	1.682	.095
	MHan	.289	.103	.289	2.798	.006
	Rou	.210	.080	.230	2.617	.010
	Vol	.082	.092	.092	.885	.378

a. Dependent Variable: CSatis

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Appendix I: Regression Analysis Manufacturing Performance Indicators on Business Performance

Profitability

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: Profit
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.874[a]	.763	.754	.39329

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	65.389	5	13.078	84.548	.000[b]
	Residual	20.263	131	.155		
	Total	85.652	136			

a. Dependent Variable: Profit
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-1.122	.281		-3.994	.000
	Qua	.141	.068	.132	2.080	.039
	Cost	.059	.078	.052	.762	.448
	Lead	.494	.091	.359	5.424	.000
	Prod	.185	.104	.162	1.781	.077
	InMi	.376	.088	.302	4.264	.000

a. Dependent Variable: Profit

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Product Market Performance

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: Market
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.682[a]	.466	.445	.59064

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.829	5	7.966	22.834	.000[b]
	Residual	45.700	131	.349		
	Total	85.529	136			

a. Dependent Variable: Market
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	-.354	.422		-.838	.403
	Qua	.186	.102	.174	1.822	.071
	Cost	.269	.117	.235	2.299	.023
	Lead	.490	.137	.356	3.580	.000
	Prod	-.220	.156	-.192	-1.411	.161
	InMi	.293	.133	.236	2.213	.029

a. Dependent Variable: Market

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Customer Satisfaction

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	InMi, Qua, Lead, Cost, Prod[b]	.	Enter

a. Dependent Variable: CSatis
b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.830[a]	.689	.677	.40742

a. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	48.110	5	9.622	57.969	.000[b]
	Residual	21.744	131	.166		
	Total	69.855	136			

a. Dependent Variable: CSatis
b. Predictors: (Constant), InMi, Qua, Lead, Cost, Prod

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.011	.291		.037	.971
	Qua	.381	.070	.395	5.421	.000
	Cost	-.120	.081	-.116	-1.491	.138
	Lead	.076	.094	.061	.808	.420
	Prod	.278	.108	.269	2.584	.011
	InMi	.368	.091	.327	4.022	.000

a. Dependent Variable: CSatis

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Appendix J: Multicollinearity Diagnostics Results

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Mix	.691	1.448
	New	.502	1.991
	Labor	.303	3.303
	Mach	.436	2.291
	MHan	.321	3.111
	Rou	.445	2.248
	Vol	.321	3.117

a. Dependent Variable: Qua

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Qua	.447	2.238
	Cost	.392	2.554
	Lead	.413	2.420
	Prod	.219	4.556
	InMi	.359	2.787

a. Dependent Variable: Market

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Appendix K: Results of Principal Components Analysis

Principal Components Analysis of Manufacturing Flexibility

Data variables:
- Mix
- New
- Labor
- Mach
- MHan
- Rou
- Vol

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 7

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	4.46171	63.739	63.739
2	0.788695	11.267	75.006
3	0.548527	7.836	82.842
4	0.405489	5.793	88.635
5	0.326711	4.667	93.302
6	0.263627	3.766	97.068
7	0.205243	2.932	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 7 variables which account for most of the variability in the data. In this case, 7 components have been extracted, since 7 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

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Table of Component Weights

	Component 1	*Component* 2	*Component* 3	*Component* 4	*Component* 5	*Component* 6	*Component* 7
Mix	0.274282	-0.885963	0.0308343	-0.0567852	-0.34986	-0.111975	0.026886
New	0.36042	0.292941	0.598943	-0.534735	-0.232957	-0.285662	-0.0611344
Labor	0.407085	0.0884496	-0.488175	-0.0876286	0.0533565	-0.138789	-0.747231
Mach	0.383092	-0.17282	0.44768	0.349118	0.698941	0.0433734	-0.103316
MHan	0.405207	0.068114	-0.443198	-0.206783	0.295296	-0.335866	0.626081
Rou	0.380641	0.28491	0.0268525	0.710501	-0.48248	-0.13585	0.131011
Vol	0.416304	0.0758391	-0.066624	-0.183575	-0.109442	0.868017	0.131792

The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

0.274282*Mix + 0.36042*New + 0.407085*Labor + 0.383092*Mach + 0.405207*MHan + 0.380641*Rou + 0.416304*Vol

where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

Principal Components Analysis of Manufacturing Performance

Data variables:
Qua
Cost
Lead
Prod
InMi

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 5

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	3.64856	72.971	72.971
2	0.571364	11.427	84.398
3	0.325271	6.505	90.904
4	0.287547	5.751	96.655
5	0.167261	3.345	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 5 variables which account for most of the variability in the data. In this case, 5 components have been extracted, since 5 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

Table of Component Weights

	Component 1	*Component 2*	*Component 3*	*Component 4*	*Component 5*
Qua	0.418651	-0.660038	0.423611	0.38872	-0.241934
Cost	0.445647	-0.364399	-0.493501	-0.639597	-0.126434
Lead	0.434078	0.503688	0.591726	-0.396731	-0.224365
Prod	0.48788	0.0702091	-0.00294378	0.132211	0.859974
InMi	0.446855	0.415851	-0.476301	0.514722	-0.368223

The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

0.418651*Qua + 0.445647*Cost + 0.434078*Lead + 0.48788*Prod + 0.446855*InMi

where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

Principal Components Analysis of Business Performance

Data variables:
Profit
Market
CSatis

Data input: observations
Number of complete cases: 137
Missing value treatment: listwise
Standardized: yes

Number of components extracted: 3

Principal Components Analysis

Component Number	*Eigenvalue*	*Percent of Variance*	*Cumulative Percentage*
1	2.33383	77.794	77.794
2	0.436927	14.564	92.359
3	0.229244	7.641	100.000

The StatAdvisor
This procedure performs a principal components analysis. The purpose of the analysis is to obtain a small number of linear combinations of the 3 variables which account for most of the variability in the data. In this case, 3 components have been extracted, since 3 components had eigenvalues greater than or equal to 0.0. Together they account for 100.0% of the variability in the original data.

Table of Component Weights

	Component 1	*Component 2*	*Component 3*
Profit	0.604776	-0.069262	0.793378
Market	0.568537	-0.660059	-0.491007
CSatis	0.557685	0.748014	-0.35981

The StatAdvisor
This table shows the equations of the principal components. For example, the first principal component has the equation

0.604776*Profit + 0.568537*Market + 0.557685*CSatis

where the values of the variables in the equation are standardized by subtracting their means and dividing by their standard deviations.

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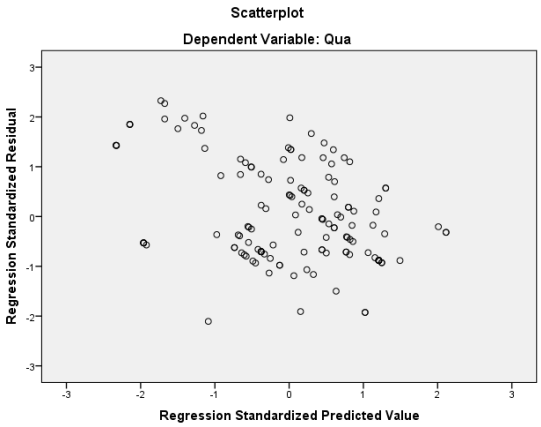
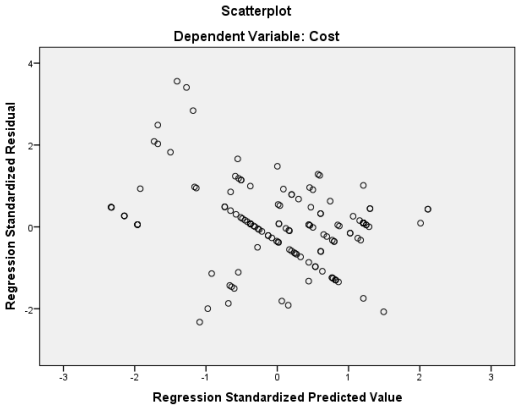
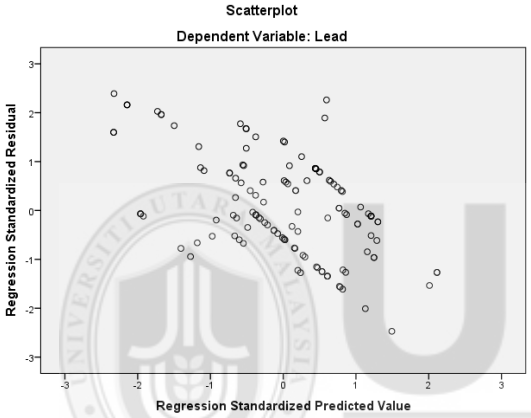
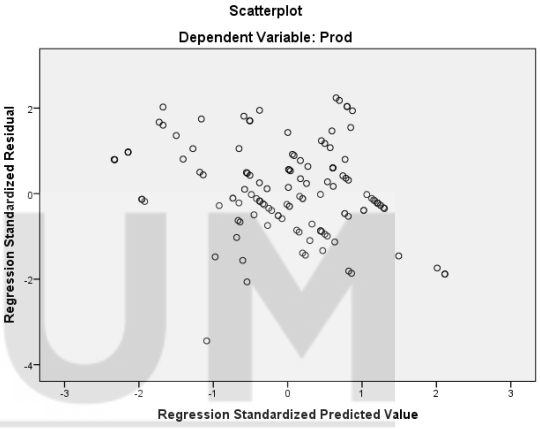
Appendix L: Standardized Residual Scatterplots

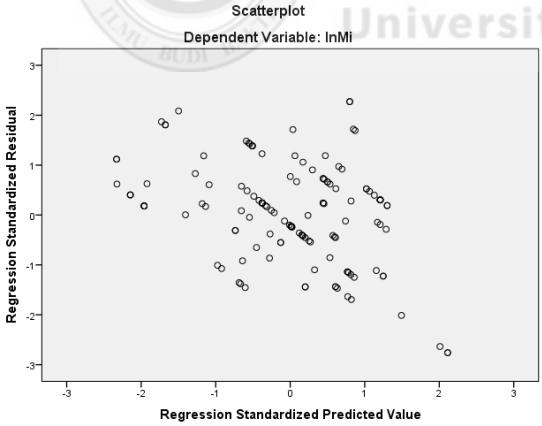
MF on MP measures











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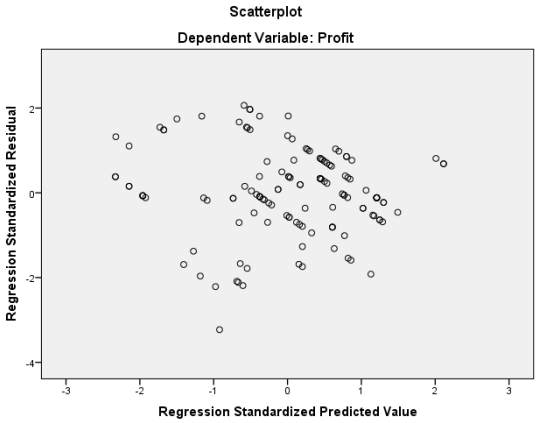
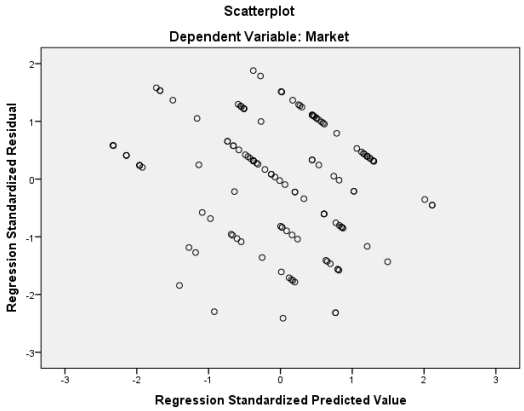
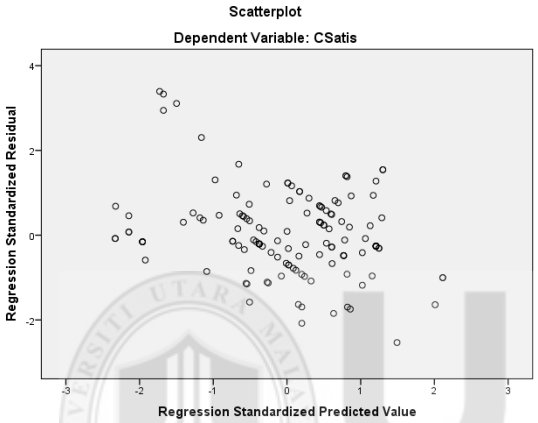
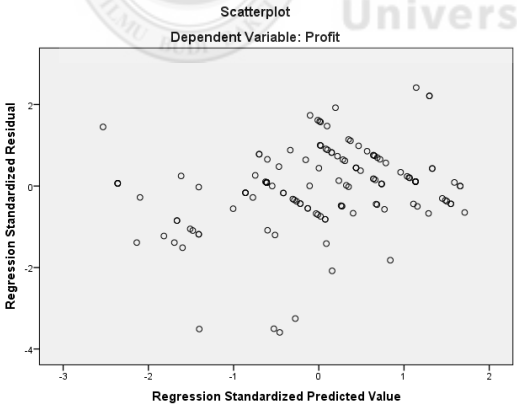
MF on BP measures

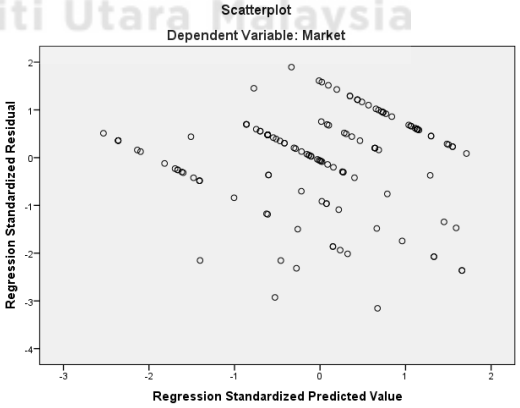






MP on BP measures





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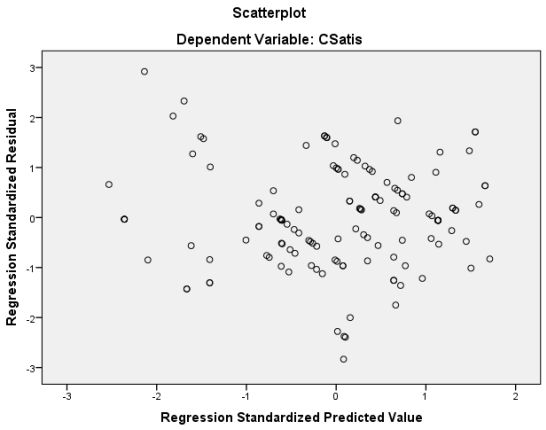

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Appendix M: Regression Analysis for Mediation Test

Regression - MF on MP

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PCAMF[b]	.	Enter

a. Dependent Variable: PCAMP

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.788[a]	.621	.618	.7896442

a. Predictors: (Constant), PCAMF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	137.963	1	137.963	221.259	.000[b]
	Residual	84.178	135	.624		
	Total	222.141	136			

a. Dependent Variable: PCAMP

b. Predictors: (Constant), PCAMF

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.953	.460		6.426	.000
	PCAMF	.607	.041	.788	14.875	.000

a. Dependent Variable: PCAMP

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Regression – MF and MP on BP

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	PCAMP, PCAMF[b]	.	Enter

a. Dependent Variable: PCABP

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.883[a]	.781	.777	.5549226

a. Predictors: (Constant), PCAMP, PCAMF

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	146.743	2	73.371	238.266	.000[b]
	Residual	41.264	134	.308		
	Total	188.007	136			

a. Dependent Variable: PCABP

b. Predictors: (Constant), PCAMP, PCAMF

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Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.654	.369		-1.772	.079
	PCAMF	.181	.047	.256	3.888	.000
	PCAMP	.614	.060	.668	10.159	.000

a. Dependent Variable: PCABP

Appendix N: PROCESS Results with Standardized Beta Weight

```
Run MATRIX procedure:

*************** PROCESS Procedure for SPSS Release 2.13.2 *************

        Written by Andrew F. Hayes, Ph.D.      www.afhayes.com
   Documentation available in Hayes (2013). www.guilford.com/p/hayes3

**************************************************************************

Model = 4
   Y = StdBP
   X = StdMF
   M = StdMP

Sample size
       137

**************************************************************************

Outcome: StdMP

Model Summary
      R      R-sq       MSE       F       df1       df2         p
   .7881     .6211     .3817   221.2585   1.0000   135.0000    .0000

Model
          coeff       se         t         p       LLCI      ULCI
constant   .0000    .0528    .0000    1.0000    -.1044    .1044
StdMF      .7881    .0530   14.8748    .0000     .6833    .8929

**************************************************************************

Outcome: StdBP

Model Summary
        R      R-sq       MSE         F       df1       df2         p
     .8835     .7805     .2228   238.2662    2.0000
134.0000     .0000

Model
            coeff       se         t         p       LLCI      ULCI
constant     .0000     .0403     .0000    1.0000    -.0798     .0798
StdMP        .6679     .0657   10.1592     .0000     .5379     .7979
StdMF        .2556     .0657    3.8877     .0002     .1256     .3856

************************** TOTAL EFFECT MODEL ************************
Outcome: StdBP

Model Summary
       R      R-sq       MSE       F       df1       df2         p
     .7820    .6115     .3914   212.4632  1.0000   135.0000    .0000

Model
            coeff       se         t         p       LLCI      ULCI
constant     .0000     .0535     .0000    1.0000   -.1057     .1057
StdMF        .7820     .0536   14.5761    .0000    .6759     .8881
```

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```
***************** TOTAL, DIRECT, AND INDIRECT EFFECTS ******************

Total effect of X on Y
    Effect        SE         t         p      LLCI      ULCI
     .7820     .0536    14.5761     .0000     .6759     .8881

Direct effect of X on Y
    Effect        SE         t         p      LLCI      ULCI
     .2556     .0657     3.8877     .0002     .1256     .3856

Indirect effect of X on Y
        Effect    Boot SE   BootLLCI   BootULCI
StdMP     .5264     .0493     .4327     .6225

******************* ANALYSIS NOTES AND WARNINGS ***********************

Number of bootstrap samples for bias corrected bootstrap confidence
intervals:
    5000

Level of confidence for all confidence intervals in output:
   95.00

------ END MATRIX -----
```

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